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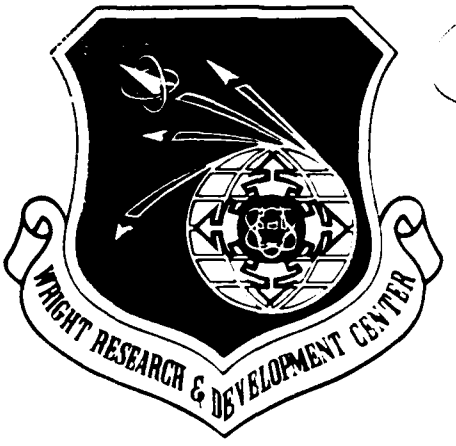

INTEGRATED INFORMATION SUPPORT SYSTEM (IISS)
Volume IV - IISS System
Part 7 - Enterprise Integration Framework (EIF) for Electronics

J. Maxwell

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Integration Technology Services
2970 Presidential Drive
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This document describes work performed in support of the Enterprise Integration Framework. It contains the Final Report produced by IBM Corporation for defining a national framework for inter and intra enterprise integration based on Open Systems and National and International standards.

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FOREWORD

This technical report covers work performed under Air Force Contract F33600-87-C-0464, DAPro Project. This contract is sponsored by the Manufacturing Technology Directorate, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. It was administered under the technical direction of Mr. Bruce A. Rasmussen, Branch Chief, Integration Technology Division, Manufacturing Technology Directorate, through Mr. David L. Judson, Project Manager. The Prime Contractor was (Integration Technology Services,) Software Programs Division, of the Control Data Corporation, Dayton, Ohio, under the direction of Mr. W. A. Osborne. The DAPro Project Manager for Control Data Corporation was Mr. J. P. Maxwell.

The DAPro project was created to continue the development, test, and demonstration of the Integrated Information Support System (IISS). The IISS technology work comprises enhancements to IISS software and the establishment and operation of IISS test bed hardware and communications for developers and users.

The following list names the Control Data Corporation subcontractors and their contributing activities:

SUBCONTRACTOR	ROLE
Control Data Corporation	Responsible for the overall Common Data Model design development and implementation, IISS integration and test, and technology transfer of IISS.
D. Appleton Company	Responsible for providing software information services for the Common Data Model and IDEF1X integration methodology.
ONTEK	Responsible for defining and testing a representative integrated system base in Artificial Intelligence techniques to establish fitness for use.
Simpact Corporation	Responsible for Communication development.
Structural Dynamics Research Corporation	Responsible for User Interfaces, Virtual Terminal Interface, and Network Transaction Manager design, development, implementation, and support.
Arizona State University	Responsible for test bed operations and support.

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SECTION 1

INTRODUCTION

1.1 Background

In September 1989, Control Data awarded subcontracts to IBM Corporation and Northrop Corporation for the Enterprise Integration Framework task. This document presents, as an unedited appendix, the IBM Workshop Briefing. DAPro document EIF 620350001 provides the final report of the Northrop effort.

1.2 Disclaimer

The conclusions presented by this document are those of the IBM EIF Team and do not necessarily reflect those of either Control Data or WRDC/MTI. The release of this document does not imply endorsement by the USAF.

SECTION 2

EIF OBJECTIVES

2.1 WRDC/MTI Statement of Work

In June 1990, WRDC/MTI released a SOW defining the Enterprise Integration Framework task. A simplified version of that SOW is presented in this section.

2.1.1 Background

The Integration Technology Division of WRDC/MTI and their cosponsors will be leading an effort to define, develop, and validate through implementations a national framework for inter and intra enterprise integration based on open systems and national and international standards. This effort will be cosponsored by the Defense Manufacturing Office of the Defense Advanced Research Projects Agency (DARPA DMO), the Computer Aided Acquisition and Logistics Support (CALS) office in the Office of the Secretary of Defense (OSD CALS), and the National Institute for Standards and Technology (NIST). This effort will begin with a preliminary strawman framework development task to serve as the catalyst for national debate and involvement in follow-on longer term programs for the development and implementation of open systems for enterprise integration. It is anticipated that a national consensus will emerge, resulting in a United States model for the development of international standard(s) for integrating many types of applications and industries. Opportunities will be sought for cooperation and coordination with other related international efforts.

This task for development of a preliminary or strawman enterprise integration framework will build off of prior and ongoing work including the European Strategic Program for Research on Information Technology (ESPRIT) consortium developing a Computer Integrated Manufacturing Open Systems Architecture (CIM OSA). For a number of reasons, the United States has been slow to respond in a unified, coordinated manner to this activity. To facilitate the design of a comprehensive enterprise integration framework, the approach of this task is not to start from scratch, but to evaluate the relevance of leveraging the ESPRIT CIM OSA effort as well as other potentially relevant existing initiatives. The resulting framework will provide a stable, low-risk strategy for coordinated investment by government and industry in automated infrastructures. The framework will also provide a common reference model for establishing research priorities, modernization of DoD activities, and standards efforts. A number of closely coordinated activities of the sponsors will support the development of the national framework initiated by the strawman framework from this effort.

2.1.2 Scope of Effort

This enterprise integration strawman framework effort shall span an eight month time period. There will be two tasks executed serially: task one shall last two months, task two shall last six months. The objective of the effort is to employ contractor expertise to work closely with a NIST-led Framework Advisory Board (FAB) to quickly assess the state of the art, develop a strawman framework, and perform a domain impact study for the framework. While the focus of the effort is primarily domain independent, the contractor shall focus primarily (but not exclusively) on aerospace enterprise issues to include an aerospace organization's interfaces to the

government and to subtier suppliers. Task 1 should not exceed 25% of the total effort; task 2 shall compose the remainder of the effort.

2.1.3 EIF Tasks

Task 1: Preliminary Scoping Document and Development Plan

1.1 The contractor shall submit a monthly status project status letter to the AFPMO to identify significant events, accomplishments, contractor/government liason activities/meetings, potential problem areas or issues, and related progress throughout this effort. The contractor shall use the IDEF methodologies and other formal structured techniques as required for reporting results when appropriate. The contractor shall develop and document a management plan for performing the activities of task 1 and task2.

1.2 The contractor shall develop an unclassified, annotated bibliography and assessment of existing material which is relevant to the framework development. Using this source material, the contractor shall extract a list of requirements, issues, measurement criteria, and sources. The contractor shall provide input to the NIST-led FAB in order to develop a single clear mission statement and criteria for evaluating the success of the framework strawman.

1.3 The contractor shall develop a list of enterprise processes, building a matrix showing how each process contributes to mitigating the issues in achieving enterprise integration. The contractor shall build a list of information classes for each process. The contractor shall develop a glossary of enterprise integration terminology to submit to the FAB and assist in the development of a single, consistent glossary to be finalized by the FAB.

1.4 The contractor shall participate as authorized by the AFPMO in government led and sponsored discussions with national and international organizations such as ESPRIT.

1.5 The contractor shall evaluate the ESPRIT CIM OSA work and any other relevant initiatives identified in subtask 1.2, and make recommendations on (a) using CIM OSA terms and definitions in the framework and in the enter-prise integration glossary, (b) extensions to CIM OSA reference architecture needed to address the issues identified in subtask 1.2, and (c) using the extended CIM OSA reference architecture to populate the framework processes in task 2.

1.6 Using the results of the previous subtask, the contractor shall develop an EIF development plan for defining a strawman framework interms of requirements, issues, enterprise processes, and information types in task 2.

1.7 The contractor shall present the results of task 1 and the EIF development plan at a government sponsored workshop. Formal approval of the plan shall be provided by the AFPMO prior to the execution of task 2.

Task 2: Development of a Strawman EIF

2.1 The contractor shall develop a strawman framework for enterprise integration based upon open systems concepts and national and international standards. The contractor shall update the glossary and submit it to the AFPMO to be finalized by the FAB.

2.2 The contractor shall provide a report analyzing the potential impact of an approved framework on current programs. Recommendations on the methods of using the framework in these programs and anticipated benefits as well as negative impacts shall be described. The

example matrix of subtask 1.3 shall be employed, showing how detailed process elements in these candidate programs map to the strawman. The following programs shall be considered:

Product Data Exchange using STEP (PDES)

DARPA Initiative in Concurrent Engineering (DICE)

Microelectronics Manufacturing Science and Technology (MMST)

Integrated Composite Center (ICC)

Integrated Design Support (IDS)

Advanced Cost Management Systems (ACMS)

Automated Airframe Assembly Program (AAAP)

any other suggested program(s)

2.3 The contractor shall produce and deliver a final Strawman EIF which shall be prepared in contractor formats. The contractor shall present the strawman framework at an end of task briefing to the AFPMO and their cosponsors and selected audiences specified by the FAB and conveyed in writing by the AFPMO. The contractor shall clearly identify all open issues and alternatives. The contractor shall present and deliver the results of this effort to the AFPMO via the Prime Contractor for continued evaluation and use.

APPENDIX A

IBM EIF TEAM WORKSHOP BRIEFING

CIM Europe 90, Lisbon, Portugal
15-17 May 1990 pp. 16-27.

MODELLING AND ANALYSIS OF ENTERPRISE INFORMATION SYSTEMS WITH CIM-OSA

F. Vernadat
INRIA-Lorraine, France
and AMICE Consortium

INTRODUCTION

Enterprise modelling and analysis methods and tools to support system design and to prepare system implementation according to system requirements are definitively required for the implementation of CIM systems. Also required to achieve full system integration is an integrating infra-structure, i.e. a software layer implemented on-top of heterogeneous operating systems, which can provide a common shared platform on which diversified system components (i.e. information technology components, manufacturing technology components and human operators) can be interfaced and through which they can communicate.

The AMICE Consortium, which groups 21 major European companies in a common ESPRIT effort, is developing CIM-OSA, an Open Systems Architecture for CIM, to address these requirements. CIM-OSA is made of a Reference Architecture for modelling the Particular Architecture of a given enterprise (or part of it) and of an Integrating Infra-Structure (IIS), which is a set of basic services used to achieve systems integration and communication built on-top of OSI-based communications facilities. CIM-OSA advantages and basic principles (Beeckman, 1989), the CIM-OSA modelling framework (Jorysz and Vernadat, 1990a, 1990b) and the CIM-OSA Integrating Infra-Structure (Klittich, 1990) have already been discussed in previous papers.

The Modelling Framework developed in CIM-OSA is based on three orthogonal modelling principles (Figure 1):

- the instantiation process based on the recognition of
  * Generic Building Blocks or basic constructs
  * Partial Models
  * Particular Models
- the derivation process consisting of
  * a Requirements Definition Modelling Level
  * a Design Specification Modelling Level
  * an Implementation Description Modelling Level
- the generation process involving four modelling views:
  * the Function View
  * the Information View
  * the Resource View
  * the Organisation View

Particular Models are models of a particular enterprise. They can be built from previously defined, incompletely instantiated, Partial Models stored in the CIM-OSA Reference Architecture and developed for well-defined industrial sectors. Partial and Particular Models are specified in terms of basic Building Blocks, also called modelling constructs.

At the Requirements Definition Modelling Level a user-specified model of the enterprise is built which defines WHAT has to be done in terms of business requirements. At the Design Specification Modelling Level consistent and non ambiguous models are developed for the four Modelling Views.

They represent possible solutions to the enterprise problems and the types of components required. Design criteria, system requirements and simulation are used to determine the "best" solution. At the Implementation Description Modelling Level an executable model is produced which indicates HOW things will be performed on implemented components to fulfil system requirements.

The CIM-OSA Function View is a modelling standpoint which allows the specification, design, analysis and implementation description of the structure, behaviour and functionality of the CIM enterprise functions.

The CIM-OSA Information View is another modelling standpoint which allows the specification, design, analysis and implementation description of the information aspects of the CIM enterprise.

The CIM-OSA Resource View and Organisation View are respectively concerned with physical components and individual responsibilities.

In this paper, we discuss how to model the information system of an enterprise according to CIM-OSA principles. However, since the analysis of the Function View of a given enterprise is a prerequisite to the analysis of its Information View, we first present concepts of the CIM-OSA Function View.

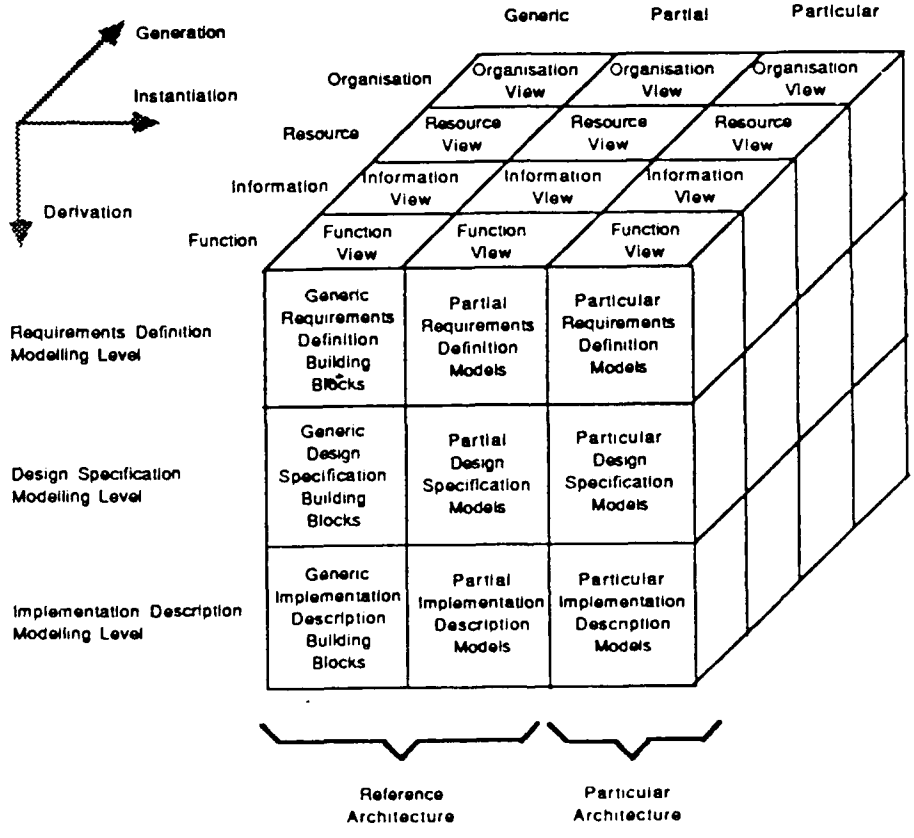

Figure 1: CIM-OSA Modelling Framework (known as the CIM-OSA Cube)

CIM-OSA FUNCTION VIEW

The purpose of the CIM-OSA Function View is to provide tools and methods to support the development of that part of the enterprise model describing system functional structure, functionality and behaviour. It concerns modelling and analysis of enterprise functions. It is based on the functional decomposition principle and largely extends previous techniques such as SADT (Ross, 1977), IDEF0 (Bravoco and Yadav 1985a, 1985b) and the like.

Basic Concepts

In CIM-OSA, any enterprise can be decomposed into a number of *Domains*, i.e. non-overlapping subsets of the enterprise realising functions of the enterprise in terms of processes (e.g. product engineering, manufacturing, production planning and control, etc.). A Domain must never be confused with an enterprise department, which means that CIM-OSA banishes the traditional Taylorism approach to enterprise decomposition which has led in the past to the creation of many so-called islands of automation.

A CIM-OSA Domain is the part of the enterprise which will be the focus of a CIM-OSA analysis (it defines the universe of discourse of the analysis). It is made of a set of *Domain Processes*, each one contributing to the realisation of some enterprise objectives under a given set of enterprise constraints, respectively known as *Domain Objectives* and *Domain Constraints*. The scope of each Domain is clearly identified by its set of *Domain Relationships* (defining the Domain Boundary) described in terms of *Object Classes* received from or sent to other Domains. Object Classes are families of enterprise objects created, processed or used by Domains. A Domain Relationship is always defined between two Domains, which are said to be adjacent.

Domain Processes are high-level constructs used to represent the major tasks to be performed in a Domain. They are composed of *Business Processes* and *Enterprise Activities*, which respectively describe the Domain behaviour (i.e. the dynamic part of the model) and the Domain functionality (i.e. the static part of the model). Domain Processes and Business Processes are triggered by *Enterprise Events* which represent external happenings (arrival of a customer order), human orders (decision to start a task) or timed actions (a process is started each day at 5:00 pm) occurring in the enterprise.

Domain Processes, Business Processes and Enterprise Activities (which appear in the Particular Model of the enterprise, i.e. the right-hand slice of the CIM-OSA cube) and their types (i.e. Partial Models) are described in terms of a unified modelling construct called *Enterprise Function* (which belongs to the CIM-OSA Building Blocks, i.e. the left-hand slice of the cube). The Enterprise Function construct (Figure 2) is used to describe each enterprise process, task, subtask, and so-on to a level of decomposition satisfactory to model and control the CIM system operations. Thus, this modelling construct can keep track of the enterprise functional decomposition (structure part) as well as the enterprise *Objectives and Constraints* decomposition (which drives the functional decomposition process). It also allows to record *Declarative Rules* of the task (i.e. combinations of objectives and constraints linked by conditions which might influence the task execution), *Procedural Rules* (which describe the behaviour of the task, i.e. how low-level tasks are used to perform that task), *Events* (which trigger the execution of the task), *Required Capabilities* (which define a set of technical limitations on the operational, functional and performance capabilities of the task), and *Inputs and Outputs* (namely function, control and resource inputs and outputs).

Enterprise Activities (Figure 3) describe the functionality of basic tasks which can be performed in various enterprises (such as move, make, verify and control) and tailored to specific business requirements (such as procurements, metal cutting or shipping and receiving activities). Their inputs, outputs and resources are well identified as views of Enterprise Objects (see Information View). They operate according to control inputs, and report about their status as control outputs, in order to transform function inputs into function outputs using resources. They are further described in the enterprise implementation model in terms of *Functional Operations*, i.e. elementary sub-tasks which can be executed via the Integrating Infra-Structure by the enterprise components, called *Functional Entities*. Functional Entities are active elements which can perform a defined set of

Functional Operations. CIM-OSA recognises data storage, application, machine, human and communication Functional Entities and Operations.

Business Processes (Figure 4) are used to describe the way Enterprise Activities are grouped into processes and how activities and processes are procedurally chained to form larger processes (such as design processes, production planning processes, manufacturing processes, etc.) to realise sub-objectives of larger enterprise objectives of a complete Domain Process.

The distinction between the concepts of Business Process and Enterprise Activity is considered as very important in CIM-OSA since it is assumed that what makes enterprises different from one another is the way they use Enterprise Activities to form Business Processes (this represents their know-how). Enterprise Activities (such as operation scheduling, FEM analysis, assembly activities, robot welding, etc.) are usually performed the same way by two competing enterprises and are subject to standardisation for a well-identified industrial sector while Business Processes are not necessarily standard.

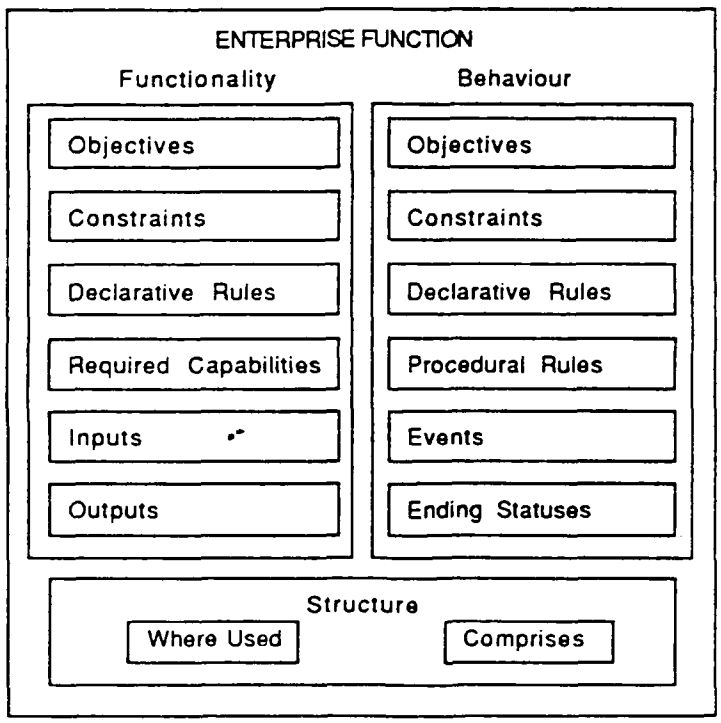

Figure 2: Enterprise Function Concept

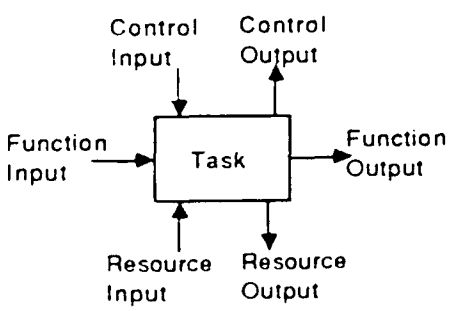

Figure 3: Enterprise Activity Diagram

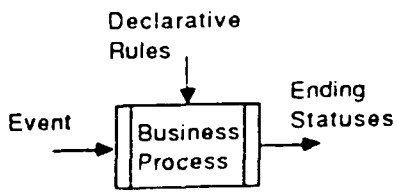

Figure 4: Business Process Diagram

Example: Manufacturing Workshop Activity Control

Manufacturing workshop activity control can be considered as a Domain as defined in the COSIMA Project (Trentin, 1990), another ESPRIT Project. This includes functions such as:

- Order Scheduling to schedule production activities on the shop floor on the basis of planned orders generated by an MRP system and to comply with due dates, priorities, availability of resources, etc.
- Order Dispatching to send real time instructions to moving and producing machines according to the detailed schedule produced by the scheduler.
- Producer Activity Control which controls specific types of production equipment of the workshop such as CNC machines, machine centres, robots and manual operations through standard protocols. It also sends status and performance data to Activity Monitoring.
- Mover Activity Control which controls workshop transport devices such as carousels, handling robots, automated-guided vehicles (AGVs) and manual handling operations. It also sends status and performance data to Activity Monitoring.
- Activity Monitoring is the feedback function. It collects real time data on equipment utilisation, materials, stock status and quality management and reports back to the order scheduler and order dispatcher or to the workshop controller.

As an example, let us assume that the CIM-OSA Domain is a FMS producing turbine blades with complex sculptured surface for gaz turbine:

Domain: Workshop Activity Control

Domain Objectives:
- to produce turbine blades made of aluminum (max. weight 1.0 Kg, max. length 1.0 m)
- to keep low work-in-process inventories
- to meet customer due dates
- to minimise lead times

Domain Constraints:
- to maintain inventory level <= $ 300 000
- to work with no more than two shifts
- cost limit (budget <= $ 700 000)

Domain Processes:
- Activity Planning
- Activity Control
- Activity Monitoring

Object Classes:
- (1) Planned Orders
- (2) Parts
- (3) Workpieces
- (4) Machines
- (5) Toolsets
- (6) Batches
- (7) Operators
- (8) Process Plans
- (9) Materials
- (10) Tools
- (11) Order Status
- (12) Performance Reports
- (13) Time Reports
- (14) Machine Instructions

Domain Relationships:
R1, R2, R3, R4.

They are described by the diagram of Figure 5 showing the object class exchanges between adjacent Domains (Domains are depicted by squared boxes with their name inside).

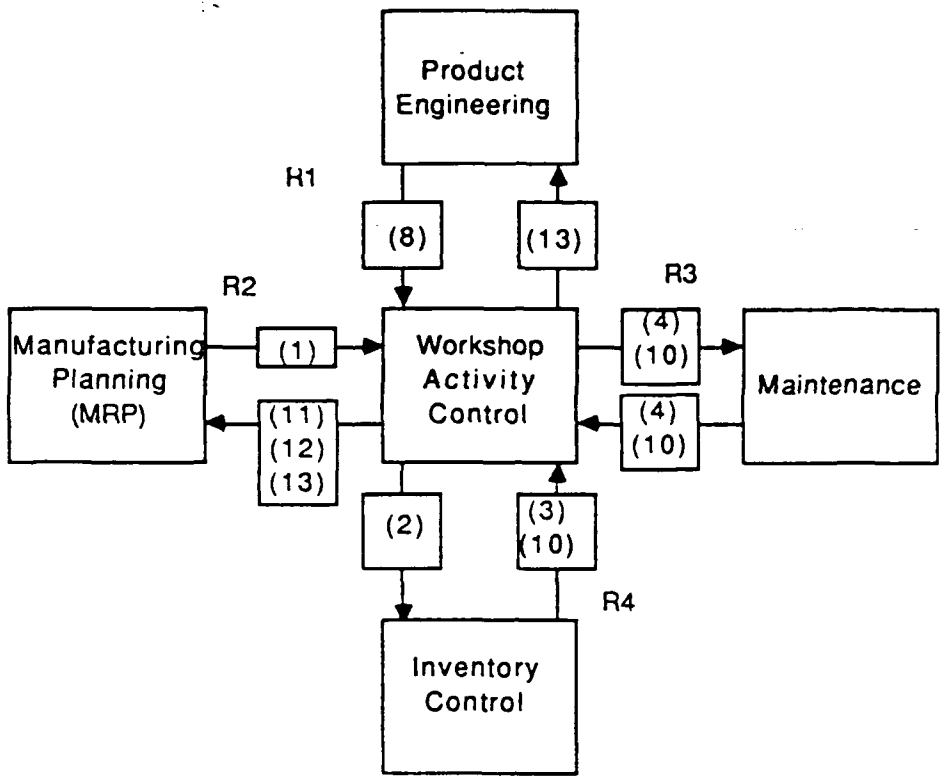

Figure 5: Domain Relationships

For this example, Domain Processes can be further decomposed into Business Processes and Enterprise Activities as follows:

DP1: Activity Planning
- BP11: Order Scheduling
  - EA111: Plan Capacity
  - EA112: Allocate Operations
  - EA113: Schedule Operations
- BP12: Order Dispatching
  - EA121: Analyse Schedule
  - EA122: Dispatch Producer Operations
  - EA123: Dispatch Mover Operations

DP2: Activity Monitoring
- EA201: Collect Data
- EA202: Report to Dispatcher
- EA203: Report to Scheduler
- EA204: Report to User

DP3: Activity Control
- EA301: Control Producer Operations
- EA302: Control Mover Operations

All these Domain components are described in more details in CIM-OSA by means of templates. As an example, the Domain Process template is given for the Activity Planning process.

DOMAIN PROCESS

Identifier:	DP1
Name:	Activity Planning

A. Functional Description

Objectives:	O11: to prepare the detailed schedule for daily workshop operations
	O12: to produce instructions for mover and producer components
Constraints:	C11: Use scheduling program ABC
	C12: No sub-contracted operations allowed

C13: Produce with two working shifts

Declarative Rules: D11: scheduling for second shift must reschedule unfinished operations resulting from first shift

Tasks:
- schedule detailed orders
- dispatch detailed orders

Required Capabilities:
RC11: must be able to schedule up to 200 operations on 60 machines in less than 15 minutes

Inputs
- Function Input: Planned Orders, Process Plans, Standard Times
- Control Input: Scheduling policy
- Resource Input: Scheduling program ABC

Outputs
- Function Output: Detailed Schedule, Mover Instructions, Producer Instructions
- Control Output: Activity Planning status
- Resource Output: Nil

B. Behaviour Description

Objectives: O13: schedule and dispatch detailed production orders

Constraints C14: Order scheduling precedes order dispatching

Declarative Rules: Nil

Procedural Rules:

No.	Wait For	Ending Status	Trigger
1.	START		Order Scheduling
	Scheduling Request		
2.	Order Scheduling	done	Order Dispatching
3.	Order Dispatching	abandon	Order Scheduling
		done	FINISH

Events: EV1: Scheduling Request

C. Structure Description

Where Used: D1: Workshop Activity Control Domain

Comprises: BP11: Order Scheduling
BP12: Order Dispatching

CIM-OSA makes use of six types of Procedural Rules to control the behaviour of enterprise processes. They include:

- Forced rule: control is passed to next task irrespective of the ending status value of the finishing task
- Go/NoGo rule: is a IF THEN conditional statement
- Conditional rule: control is passed to a subsequent task selected from a set of possible tasks according to the value of the ending status of the finishing task
- Spawning rule: allows for parallel execution of several tasks
- Rendezvous rule: control is passed to next task when all preceding tasks are finished
- Loop rule: allows for iterative execution of some task(s)

The flow of control (Procedural Rules) or the flow of information and materials (inputs and outputs) of Enterprise Functions can be illustrated using symbols of Figures 3 and 4. Figures 6 a) and b) illustrate the behaviour (i.e. the set of Procedural Rules) of Domain Process DP1 (Activity Planning) and Business Process BP12 (Order Dispatching). Figure 7 illustrates the flow of information for BP12.

Nota: Domains must not be regarded as "islands of automation" since (1) Domain Relationships (i.e. Domain interactions) are clearly established and specified, (2) Domains must contain entire Business Processes, and (3) CIM-OSA provides the necessary integrating infra-structure to support information exchange between the various enterprise Domains.

CIM-OSA INFORMATION VIEW

The purpose of the CIM-OSA Information View is to provide tools and methods to support the development of the information model of the Domains analysed. It makes use of three modelling paradigms, one for each modelling level. At the Requirements Definition Modelling Level, a semantic object-oriented modelling approach is used. At the Design Specification Modelling Level, an extended entity-relationship approach is used which is based on the M* methodology (Vernadat et al., 1989). At the Implementation Description Modelling Level conventional data modelling techniques are used. The global modelling framework is compliant with the three-schema approach proposed by ANSI (ANSI/X3/SPARC, 1976), which advocates for the use of a global conceptual schema implemented in terms of an internal schema and presented to system users via external schemata.

Basic Concepts

At the Requirements Definition Modelling Level, enterprise requirements are decribed in terms of *Enterprise Objects* and *Object Views*. In fact, what users use and manipulate in their day-to-day operations are Object Views rather than true Enterprise Objects, i.e. a description of a particular aspect of an Enterprise Object. Furthermore, we assume that inputs and outputs of any kind of Enterprise Functions are Object Views only. Therefore, analysis of the enterprise information system must start with functional analysis to identify all enterprise object views and then to derive the structure of enterprise objects. Both Enterprise Objects and Object Views are defined in terms of their *Information Elements*, i.e. any items of information which, for the purpose they are being used, are indivisible and which are characterised by a type (simple or complex data type). Any kind of *Integrity Rules* can be defined on values of Information Elements to describe existence, conformity or validity constraints. Enterprise Objects are connected to one another by means of *Object Relationships*, i.e. user-defined links, or *Object Abstraction Mechanisms*, i.e. natural semantic links. Four abstraction mechanisms are being used in CIM-OSA (Peckam and Maryanski, 1986):

- Generalisation (or ISA link)
- Aggregation (or PARTOF link)
- Classification (or INSTANCEOF link)
- Association (or MEMBEROF link)

Graphically the model is a semantic network in which nodes are squared boxes which represent Enterprise Objects and oriented arcs are Object Relationships. Object Abstraction Mechanisms are arcs labelled with G for generalisation, Ag for aggregation, C for Classification and As for association.

At the Design Specification Modelling Level, a Conceptual Schema must be defined as a consistent and non ambigous data structure representing static and dynamic properties of data and information. The static part is described in terms of an entity-relationship-attribute (ERA) model as defined in the methodology M* (Vernadat et al., 1989). This formalism is based on the concept of entities, relationships along with their cardinalities, attributes, internal and external identifiers, and two abstraction hierarchies which are special cases of the ISA link (Figure 8). The dynamic part is described by (1) *Database Transactions* which are sets of operations to be executed on the

database and considered as a whole, and (2) by *Integrity Constraints* which are formal expressions of Integrity Rules in the ERA formalism. Furthermore, External Schemata must be derived from the Conceptual Schema to describe the Object Views in the ERA formalism or to specify detailed user views of the data. CIM-OSA provides translation rules to convert the object-oriented model into an ERA model. The ERA model can be fully formally described and used for simulation purposes.

At the Implementation Description Modelling Level, an Internal Schema of the information system must be described in an executable form. This is achieved by a two-stage process. First, a *Logical Data Model* is produced. This is a direct translation of the structure of the Conceptual Schema and its External Schemata in ERA form into classical data model formalisms (relational, hierarchical, network) (See Date, 1986). Next, a *Physical Data Model* is produced as the final form of the Internal Schema. It consists of an optimised data structure of the information system with index definitions, user access authorisations, partition definitions and integrity constraints specification, all specified in the data definition languages of the implementation data storage systems (such as relational database management systems).

Example

As mentioned earlier, function inputs and outputs of Enterprise Functions are Object Views. For a given Domain, they have been identified during the Function View analysis. They need to be specified in the Information View and their underlying Enterprise Objects must be described. As an example, we provide the description template for the Enterprise Object "Process Plan" and for "Opeline", a sub-object of the Process Plan object.

ENTERPRISE OBJECT
Identifier: EO-15
Name: Process Plan
Description: Describes the sequence of operations to manufacture the part
Abstraction Relationships:
Isa: Nil
Partof: Part Description
Memberof: Nil
Properties:
Partcode
Designer
CreationDate
Version
Operations: Setof Opeline

ENTERPRISE OBJECT
Identifier: EO-16
Name: Opeline
Description: Describes one line of a Process Plan
Abstraction Relationships:
Isa: Nil
Partof: Process Plan
Memberof: Nil
Properties:
SequenceNumber
OpeCode
OpeDesignation
MachineType
SetupTime
RunTime
Labour

All object properties are either Information Elements or Enterprise Objects or a set of (Setof) Information Elements or Enterprise Objects. For example the Information Element "OpeDesignation" can be described by:

INFORMATION ELEMENT
Name: OpeDesignation
Short Description: Abbreviated description of a manufacturing operation
Data Type: Character string [30]
Related Objects: Operation, Opeline
Composed of: Operation name, operation instructions
Synonym: OpeDescr

Object Views are incomplete object descriptions and are also defined in terms of Information Elements. Object Views and Enterprise Objects are then transformed into an entity-relationship-attribute model. Figure 9 gives an example of such a model for workshop control. Simple Enterprise Objects (i.e. objects only made of Information Elements) are usually directly converted into entities and Object Relationships into entity relationships. Complex objects need to be converted into several entities and their links must be analysed carefully, resulting in the creation of extra relationships.

This model can then be translated into a relational model using CIM-OSA rules for schema derivation to produce the Logical Data Model of the Internal Schema. A short example of such a model follows for the schema of Figure 9.

Relational Logical Data Model:

Part (partid, type, status, location, material, process_plan_id, NC_program, inspection_pgm)
Plan (process_plan_id, partid, alternate_plan_id, particularities, designer)
Operation (operationid, Opecode, type, designation)
Plan_Ope (plan_id, SeqNumber, Opeid) Mach_Ope (machineid, opeid)
ProducerOpe (Opeid, Machineid, Toolid, cut_type, setup_time, run_time, labour, rate_code)
MoverOpe (Opeid, Machineid, movetype, from, to, quantity)
Tool (toolid, tool_code, type, condition, location, tool_life)
Tooling (tool_code, tool_material, max_speed, min_speed, max_feed, min_feed, max_depth_of_cut, min_depth_of_cut, average_tool_life, tool_geometry)
Machine (machineid, type, condition, status, work_hours)
Standard_Time (Opecode, partid, machineid, std_setup_time, std_run_time, std_labour)
Fixture (fixtureid, type, designation, condition, location)
Fixture_Part (fixtureid, partid)
Part_Fixture (partid, fixtureid, name, mounting_instructions)
Lot (lotid, partid, quantity, priority, status, due_date, start_date, finish_date)
Schedule (cellid, lotid, start_date, finish_date, priority)

CONCLUSION

CIM-OSA is a modelling framework and an integrating infra-structure for CIM environments. In this paper we have introduced the Function View and the Information View of CIM-OSA using a manufacturing example. It is believed in the AMICE Project that the CIM-OSA framework largely enhances previous modelling approaches though the Resource and Organisation Views are still being engineered. The concepts being provided by the modelling framework need to be understood by the underlying CIM-OSA Integrating Infra-Structure (IIS) so that the model can be executed. This issue is currently receiving special attention in the project and demonstration prototypes are under development. CIM-OSA is currently beingconsidered by various standardisation bodies (national and international). Also, several ESPRIT Projects are considering the use of CIM-OSA for modelling purposes.

Acknowledgements

The author is grateful to K. Kosanke, AMICE Project Manager, and to his AMICE colleagues, namely R. Gaches, K. Farman, H.R. Jorysz, G. Müller, P. Russell, P. Viollet and M. Zelm, who contributed to this work.

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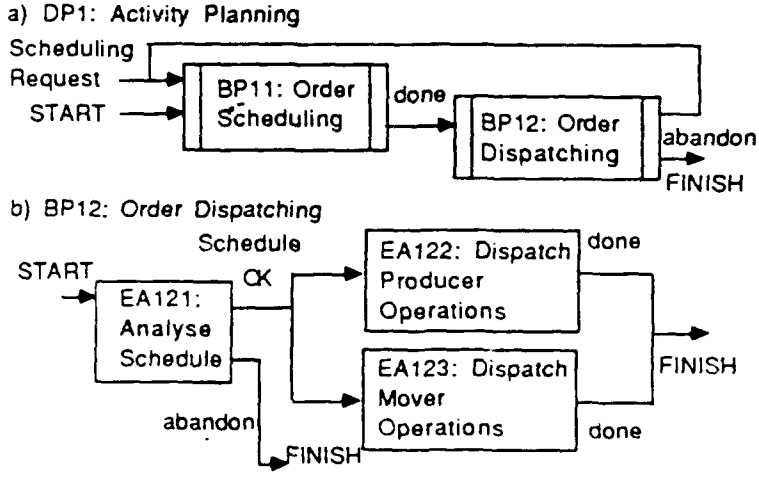

Figure 6: Flow of Control in Activity Planning

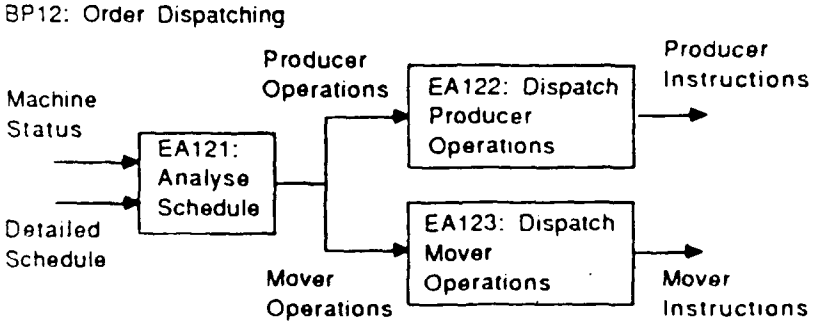

Figure 7: Flow of Information in Order Dispatching

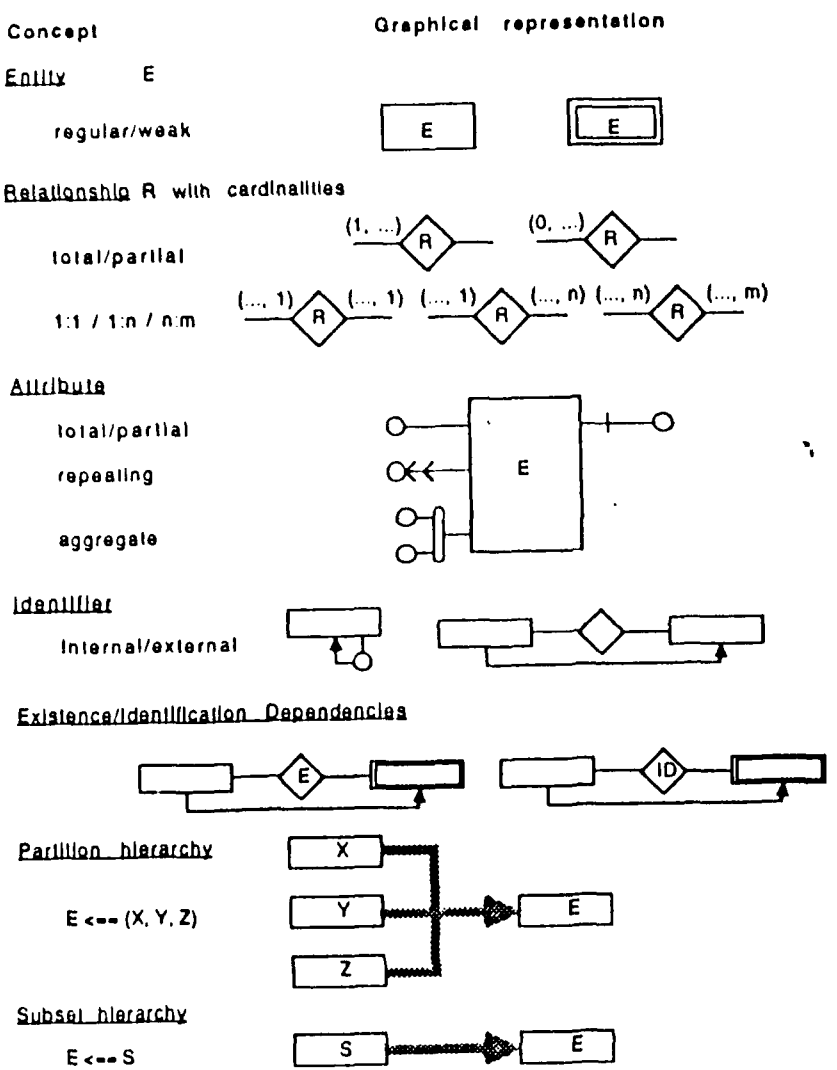

Figure 8: Entity-Relationship-Attribute Model

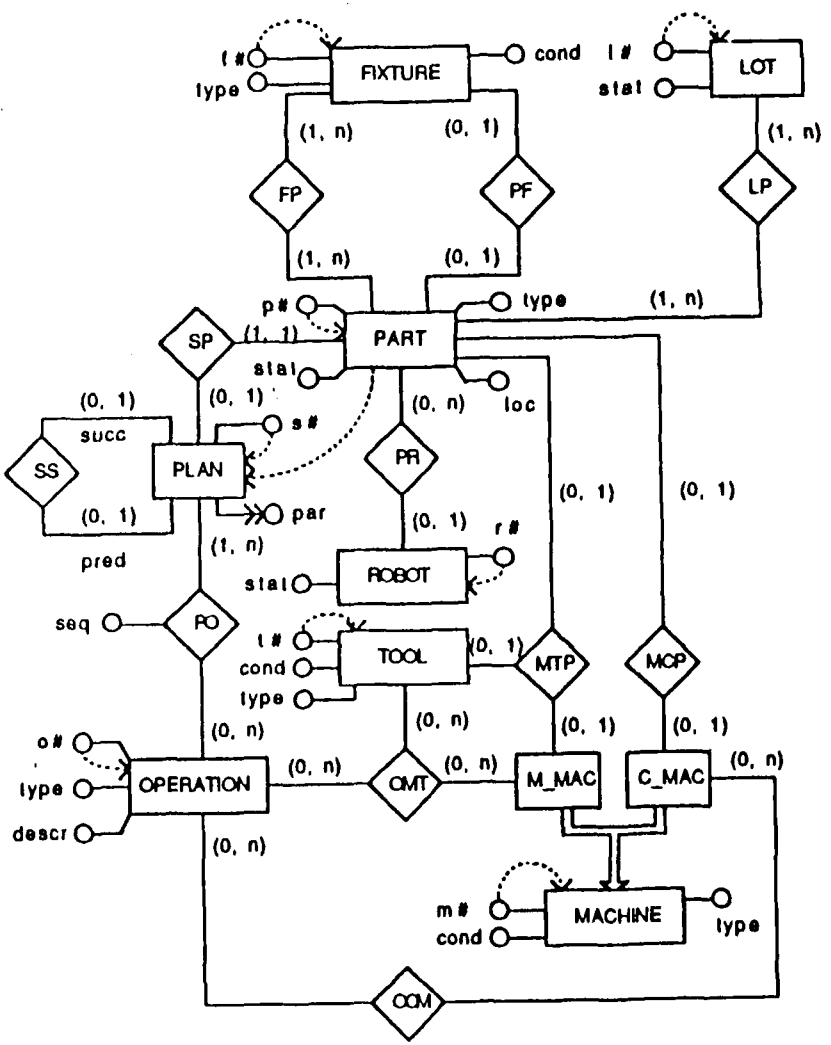

Figure 9: Example of Data Schema

ENTERPRISE INTEGRATION FRAMEWORK
FINAL REPORT

Document Number EIF-M89-25

10 September 1990

Prepared For:
Wright Research and Development Center (WRDC)
Integration Technology Division
Wright-Patterson Air Force Base, Ohio. 45433

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Preface

The Enterprise Integration Framework Study Task was performed by IBM as a task under the Control Data Corporation DAPro Contract (#F33600-87-C-0464) for the Air Force Wright Research Development Center. The Rensselaer Design Research Center, at Rensselaer Polytechnic Institute, provided supporting research under subcontract to IBM.

The objective of the EIF Study task was to define a national framework for inter and intra enterprise integration based on:

- Open Systems.
- National and international standards.

The task was initiated in October of 1989 with a meeting in Brussels, Belgium with participants from the AMICE consortium in Europe and representatives from the United States (government and EIF Study participants). The first phase of the study included a framework needs analysis, review of the existing CIM-OSA and SEMATECH frameworks, and recommendation for strawman definition activities. An Enterprise Integration Framework Working Group was formed to review the results of the study activities, assess the national framework needs from an executive perspective, and make recommendations to the government sponsors for follow-on actions. After an initial EIFWG review, a second phase of the study was initiated, including the initiative positioning, scenario investigations, and technology investigations. The task was completed in July of 1990 with a final workshop presentation at Dayton, Ohio. The workshop was attended by interested industry representatives.

This EIF Study Task Final Report provides a summary of the major activities performed and the resulting findings. The Final Report includes the following sections:

Executive Summary: Concise review of background, technical considerations, and conclusions.

Technical Summary: Describes the approach and results of the EIF study activities.

Conclusions: A summary of the technical findings and recommendations.

The following technical reports should be referenced for additional information:

EIF-M89-22 EIF Scenario Investigation

EIF-M89-23 EIF Repository Investigation

EIF-M89-24 EIF Final Workshop Briefing

IC-EJG-843-050-006 EIF National Initiative Program Positioning

In addition, the following documents which describe the AMICE Computer Integrated Manufacturing - Open System Architecture (CIM-OSA) are recommended:

1. ESPRIT Consortium AMICE (eds.): Open System Architecture for CIM, Vol., Research Reports ESPRIT Project 688.
2. CIM-OSA Story Board, (ESPRIT Consortium AMICE, Avenue Louise 489, 8th Floor, B-1050 Brussels, Belgium)

Contents

EXECUTIVE SUMMARY

The Enterprise Integration Framework Study was conducted to define, for national consensus, a disciplined framework that would promote US industrial competitiveness through enterprise integration. There are many projects, programs, and initiatives that have set out to build this type of framework. Therefore, the study emphasized a strategy for framework development by integration of existing efforts rather than independently creating a new one.

The study included four major activities:

1. Developing The Needs For A Framework
2. Positioning Existing Initiatives
3. Evaluating Framework Application
4. Investigating Framework Supporting Technology

The needs for a framework were developed from a business management and technical completeness perspective. There is a torrent of books and articles[1] which provide lists of issues, diagnoses, and prescriptions for solutions to the U.S. manufacturing competitiveness. These solutions were summarized into five actions which an enterprise integration framework must support. These are:

1. Continually strive for excellence in meeting customer demands.
2. Rapidly revise or introduce new products and technology.
3. Understand and simplify every function in the enterprise.
4. Dynamically manage the processes in the enterprise.
5. Manage an explosion of data, information, and knowledge.

To support the development of a general framework, these resulting actions must be descriptive and not specifically prescriptive. Also, the EIF Study focused on the technical aspects of integration for these actions, although it is recognized that the cultural aspects are at least as important. Finally, a complete enterprise integration framework requires a structure and methodology that supports the accurate description of all aspects of the enterprise, and is supported by an open, heterogeneous, integrated environment.

The AMICE CIM-OSA framework was accepted as the most conceptually complete of the existing, reviewed initiatives. It is important to note that CIM-OSA is being developed by a consortium of companies that include manufacturing (users), information technology, and system integration industries. Also, one reference used for CIM-OSA was the U. S. Air Force Integrated Computer Automated Manufacturing (ICAM) program.

Figure 1 on page 2 summarizes the EIF principles that allow industry to continually strive for excellence and become a superstar in a world-wide marketplace. Through the use of Reference Models, enterprise modelling, the Business Descriptive Language/Descriptive Language, and methodology, an enterprise can institute a continuous cycle to understand and improve the enterprise functions. Executable models allow simulation so these improvements can be introduced rapidly while reducing interference to the enterprise operations. The Integrating Infrastructure (IIS) allows the enterprise to dynamically manage its operations through enhanced internal and external communications and dynamic management of enterprise resources. Large volumes of data are described in the models and managed through the IIS services and standard protocols in a transparent manner.

[1] Refer to the BIBLIOGRAPHY for a representative listing of sources used.

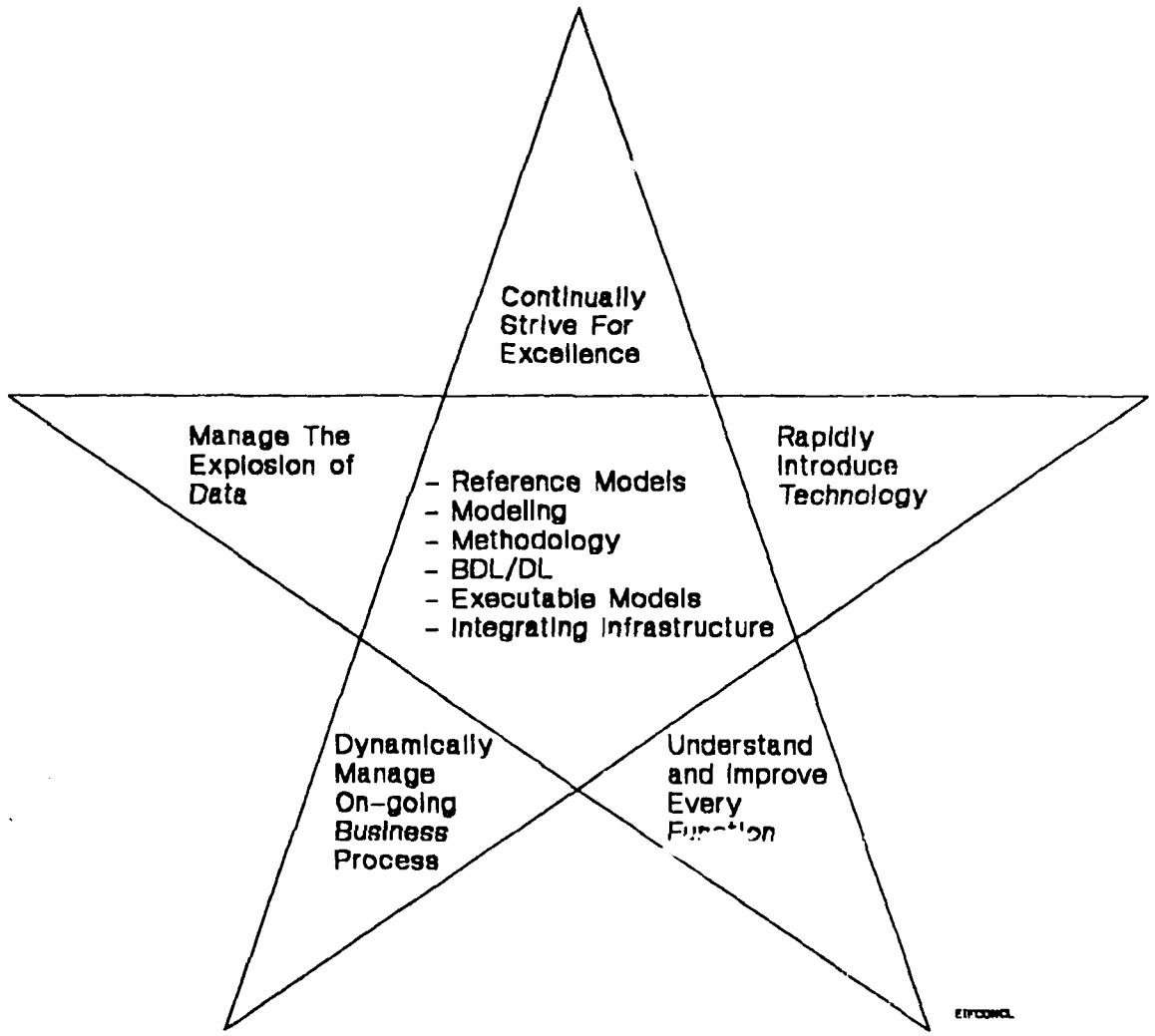

Figure 1. Required Actions Integrated By Framework

The positioning of existing initiatives summarized the enterprise integration framework characteristics already being addressed by individual programs. The positioning also included collective views, that identified the areas of coverage, if all programs were integrated. Thirteen (13) consensus initiatives were reviewed. These represented government programs, industry initiatives, and university programs. All the initiatives address aspects of enterprise integration, and include overlapping as well as unique aspects. Without additional interaction between initiatives, the potential synergistic benefits might not be realized. Generally, the initiatives with the more implied, robust capabilities were in the conceptual phase of definition. It is important to note, that generally it is easier to accommodate changes in this early development period; thus providing more opportunity to influence the pending design specifications and products through cooperative interaction.

The application of the framework principles depicted in Figure 1 was evaluated through Scenario Investigations. The Scenario Investigations were conducted in order to identify a strawman framework, demonstrate the application of framework concepts, depict the benefits provided by the framework, and identify the types of tool requirements. The Scenario Investigation Report includes a high level summary of CIM-OSA concepts and includes an example of the applicability of IDEF to the modeling requirements of CIM-OSA. The Scenario Investigation includes a Enterprise Integration Roadmap Application (EIRMA); this demonstrates how the framework concepts can be applied to an enterprise life cycle. Also, a life cycle methodology

for the creation of the associated models and enterprise plans is described. The scenario investigations showed:

- Although the CIM-OSA work is the most comprehensive, the support environment (modelling techniques and tools) for the life cycle methodology are incomplete.
- Reference Models and standard protocols must be developed to build inter and intra enterprise integration opportunities.
- The realizable benefits resulting from modeling are limited since generally existing models are not executable.

The Technology Investigations included modeling evaluations conducted by RPI RDRC and the repository investigation. The modeling evaluations included a sample EXPRESS CIM-OSA information model, modeling languages comparison and an enterprise modeling evaluation. The modeling indicated that:

- Enterprise models require a combination of process and information models.
- The EIF model will be similar to developing an extremely large software system, and except for STEP, there is a limited experience base.
- An "EIF system architect" will be essential to affect a solution.

The repository investigation identified thirteen (13) object-managers that are required to provide a dynamic information management system. These managers can be defined to be compatible with the CIM-OSA Integrated Infrastructure requirements. The repository report identified:

- An open system requires a self-defining and extendable architecture.
- An object-oriented approach could implement this open systems capability.

The four major activities described above provided technical definition for a disciplined framework for enterprise integration. An enterprise framework requires national consensus and implementations to realize increased US industrial competitiveness.

An EIF Working Group was formed to review the results of the study contract activities, assess the national framework needs from an executive perspective, and make recommendations to the government sponsors for follow-on actions. The EIF Working Group was comprised of industry, government, and university representatives. The working group reviewed preliminary technical findings at three meetings (1/90, 4/90 and 5/90). Feedback from the EIF Working Group was reflected in the study activities.

Finally, the EIF study was directed toward defining a strawman framework which could be further developed through national consensus. A strawman based upon CIM-OSA was defined by the scenario and repository investigations. Recommendations for further development through national consensus are provided in this final report.

A consistent observation experienced by the studied initiatives was that gaining consensus is a slow starting, time consuming process. It requires commitment toward a common goal, allotment of sufficient time to incorporate diverse perspectives and objectives; plus it must provide a mechanism for stability and control. Additionally, the Enterprise Integration Framework represents a very complex system of cultural aspects and technical viewpoints which complicate the consensus process.

The following recommendations resulted from the EIF Study Activities:

1. Implement a common architecture starting with the CIM-OSA definition. Incorporate existing and future DoD Initiatives in refining, extending, and validating the CIM-OSA definition.
2. As a Test Case, develop a common DoD Procurement Process description utilizing/extending the EIF Roadmap and Methodology in a consensus environment. The purpose is to provide a model for inter enterprise integration between the Government and Defense Industry.

3. Plan incremental introduction of EIF based on requirements and technology capabilities.
4. Validate the feasibility of integrating existing information models into a CIM-OSA reference model and define support tool requirements.
5. Demonstrate resulting capabilities in selected DoD industry sites.
6. Define a U.S. designated interface to ESPRIT AMICE to define the joint development plans.

Adoption of the EIF principles means that U.S. industry can do it better, less expensive, and faster. The resulting benefits are shown in Figure 2. Through the Integrating Infrastructure the Chief Executive Officer (CEO) can enhance communications between his or her team including business partners and subcontractors. The CEO can more efficiently manage the business by establishing metrics and communicating them, along with customer demands, as objectives and constraints through an integrated planning, development, and operations environment. The engineering team can reduce non-value add functions and rapidly introduce new technology and changes while lowering development costs and cycle times. Enterprise operations will become more efficient through dynamic management of resources, and transparent data and communications management allowing improved performance with reduced operational and maintenance costs. The net result for the CEO is an integrated team that will improve quality while reducing costs and cycle times.

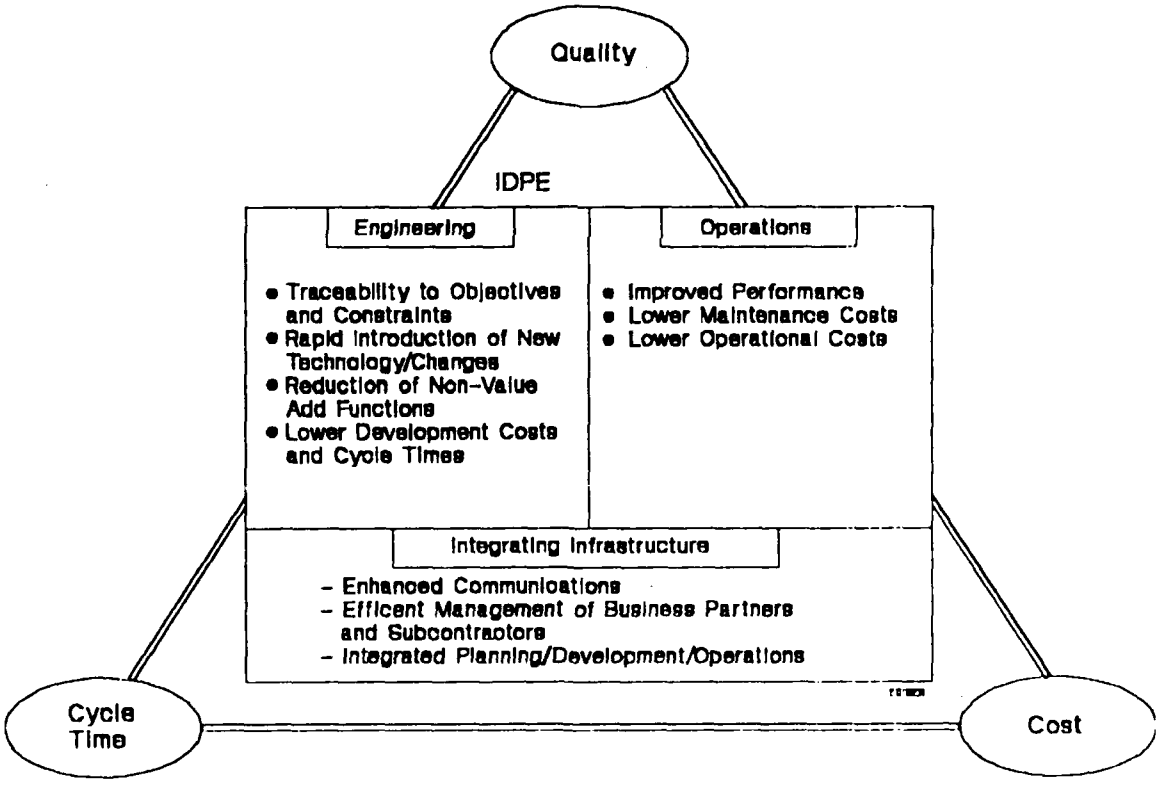

Figure 2. Framework Benefits In Application

TECHNICAL SUMMARY

BACKGROUND

The competitiveness of U.S. manufacturing is a fundamental element of the U.S. defense posture. Advanced technology leadership and defense productivity are even more critical for sustained systems capabilities in an era of declining defense spending. The issues of U.S. competitiveness are an industry problem, jointly being addressed by industry, government, and universities. Many existing programs, consortiums, and initiatives have been formulated to address different aspects of the competitive problem. As a result, many significant recommendations, technologies, and management approaches are evolving to support the improved competitive position of U.S. Industry. However, a single unified vision which inter-relates the various aspects and solutions into a common, consistent, and complete representation is not apparent. Many people already recognize the need for cooperative development but without a unifying vision the opportunities for cooperation become less apparent.

This common need was recognized by the DoD CALS policy office, Wright Research and Development Center (WRDC), and the National Institute of Standards and Technology who acted as the government sponsors for the EIF program. An Enterprise Integration Framework was postulated as an approach to define the requirements for inter and intra enterprise integration in an open environment. This framework would provide a common structural definition which could be used to facilitate cooperation between initiatives and identify areas where further extensions are required. The EIF Study contracts to define a strawman Enterprise Integration Framework were initiated by the Manufacturing Technology Directorate within WRDC.

Two EIF study contracts were awarded to IBM and Northrop Aircraft Division. The study contracts represented different perspectives on the EIF study. The IBM perspective was to establish a framework (reference system) from which the essential enterprise activities of (1) business understanding and simplification, (2) enterprise modeling, and (3) information system architecture would be consistently formulated. The contractors and Air Force representatives conducted joint technical reviews on a quarterly basis. Both contractors perspectives were supportable from a common underlying framework.

Additionally, an EIF Working Group was formulated to review the study contractor results and make recommendations to the EIF government sponsors. The EIFWG included representatives from Anderson Consulting, Boeing Commercial Airplane Co., Deere & Co., Digitial Equipment Corporation, ESPRIT Consortium AMICE, General Motors (EDS), Industrial Technology Institute, International Business Machines, McDonnell Douglas Corp., Martin Marietta, Massachusetts Institute of Technology, Northrop, Pymatuning Group, SEMATECH, South Carolina Research Authority, Westinghouse Electric Corp., and the government sponsors.

The AMICE CIM-Open Systems Architecture, an existing candidate framework, and other framework like programs in the U.S. were evaluated in the first phase of the study. This phase included a summary of the needs for enterprise integration, an outline of the requirements for a framework, and the formulation for a plan for defining a strawman framework. A strawman EIF was developed and the existing initiatives positioned against that strawman.

In phase two the focus of the EIF Study was on the integration technology issues. Although issues such as cultural, economic, and policy are significant to manufacturing competitiveness, the integration framework provides the basis for an information system representation of the enterprise, business management, financial, and other issues that are addressable through the capabilities provided by an integration framework. The framework benefits cannot be fully realized until components, especially reference models, of the framework are developed.

The study activities initiated with a U.S./AMICE three day meeting in Brussels to review CIM-OSA and obtain documentation. The U.S. group consisted of representatives from the National Institute of Standards and Technology, the Manufacturing Technology Integration Technology Division, the Computer-aided Acquisition and Logistics Support (CALS) office, and the EIF contractors' representatives. The main objectives of the AMICE project are:

- to enable fast, economic utilization of advanced technologies in industry.
- to ensure long range, evolutionary CIM implementation and growth
- to enable and support independent development of CIM building blocks.

CIM-OSA is an emerging standard in the European Economic Community and is under consideration in the International Standards Organization. The conceptual work has been completed, but significant specification, development, and validation work is still required. Since CIM-OSA is being considered as an international standard, the U.S. needs to validate that CIM-OSA satisfies U.S. enterprise requirements. Whether this includes U.S. cooperation with the AMICE must be decided. The EIF Study suggests that cooperation is required, and this is reflected in the recommendations.

The EIF Study completed with an end of contract workshop in Dayton, Ohio. Presentations were provided by the study contractors and Air Force participants. A strawman EIF based on CIM-OSA was presented, the findings from the study activities were summarized, and the recommendations were reviewed. An EIF Workshop Presentation report which includes the charts and the associated script was prepared, and provides a comprehensive review of the EIF Study results.

The following paragraphs summarize specific aspects of the EIF study activities.

PROBLEM STATEMENT / OBJECTIVES /SCOPE

The Enterprise Integration Framework (EIF) task was an effort to define and develop for national consensus a disciplined approach or framework that will promote US industrial competitiveness through enterprise integration.

America's manufacturing competitiveness has been the subject of a torrent of books and articles. The lists of issues, diagnoses, and prescriptions are many. The list of issues might include that US industries must: lower product cost, improve quality, reduce inventory, shorten lead times, integrate data, and do these on a continuing basis. Of course, each of these issues generates its own list of issues, diagnoses, and prescriptions.

These were summarized into five categories. To remain in or regain a competitive position, US industries must:

1. CONTINUALLY strive for EXCELLENCE in meeting customer demands, while keeping the customer view of the requirements in balance with management's view of the enterprise's mission, products, processes, and operating environment (internal and external).
2. RAPIDLY revise or introduce new products and RAPIDLY introduce new technologies into the products and processes without significant impact to the operation of the enterprise.
3. UNDERSTAND and IMPROVE every function in the enterprise, through attention to detail and encouragement of change.
4. DYNAMICALLY MANAGE the on-going set of PROCESSES that are required to operate the enterprise and accomplish the actions needed to achieve a competitive position.
5. MANAGE an explosion of DATA, representing data, information, and knowledge which describe the internal and external enterprise environments.

These actions are applicable not only to a specific enterprise (intra enterprise), but also must be managed in a worldwide competitive context including the activities of customers, suppliers, and trading partners (inter enterprise). This is particularly true in the DoD industry, where partnership development of major weapon systems is a requirement. Inter enterprise integration requires the implementation of (information) technology that enables not only the electronic integration and exchange of data within the enterprise, but also enables on a global scale the sharing of knowledge (meaning, context, purpose, etc.) regarding the data. Examples would include the STEP and EDI standards currently in development.

THE PROBLEM THAT MUST BE ANSWERED IS HOW TO DEFINE, POPULATE, AND USE THE FRAMEWORK FOR ENTERPRISE INTEGRATION? This question leads to:

1. THE DEFINITION OF THIS FRAMEWORK. Is it a method by which business goals and objectives at all enterprise levels are defined, connected, etc., is it a structure in which ideas are pulled together to create something, or is it an architecture (as defined by the information systems developers), or is it all of the above?
2. THE BOUNDARY DEFINITION OF THE FRAMEWORK. That is, for the industrial enterprise, what are the major highest-level objects that are needed to describe the enterprise?
3. THE NEXT LEVEL OF DETAIL THAT IS NEEDED TO FURTHER DEFINE THE BOUNDARIES. What are the major items that are needed to define the highest-level objects?
4. THE RULES, PROCEDURES, GUIDELINES, STANDARDS, etc. THAT ARE NEEDED TO GUIDE THE POPULATION OF THE FRAMEWORK.
5. SOLUTIONS THAT MIGHT ADDRESS SOME OF THE COMPETITIVENESS ISSUES. (THE SPECIFIC FOCUS IS SOLUTIONS THAT RELATE TO DATA INTEGRATION.)

As we address the objective to establish a reference enterprise integration framework, we must keep focus on the broad goal of establishing the capability to design, develop, integrate, and deploy systems and applications that support the understanding, objectives, definition, and operation of the enterprise in an environment that supports electronic exchange of data, is physically distributed, and heterogeneous, and combines both legacy systems and new technology systems. This implies the need for a framework that must support: (1) A set of integrated models which clearly and concisely define the relationships of objects within and shared between enterprises. (2) A means to describe the current enterprise operational environment, the desired operational environment, and the incremental evolution migration path. (3) The variety of tools and methods that will be needed to implement the required systems and applications. (4) A means to verify/test any decisions.

The *implications* are that this framework will help build a competitive enterprise through formal understanding of the business, build a basis for managing continual improvement, enable real-time adaptation (change), decouple business process changes from system product development, and integrate data within (across) enterprises. The scope of the framework was recommended to be descriptive based upon which prescriptive solutions for specific enterprises, industry segments, or other initiative solutions could be provided.

The key is to recognize that people are addressing the problem, but they are focused on different levels of the enterprise or on specific solutions to issues. Thus, our objective becomes building the top level framework that integrates the appropriate existing frameworks and solutions. We must develop recommendations that will allow the utilization and improvement of this integrated set of frameworks, accelerate the implementation of solutions that will improve competitiveness, and provide focus to research and development.

In summary the framework must include:

1. Structure in the form of a conceptual definition (top level boundary) and a detailed definition (models and relationships) of objects within the framework.
2. Methods that account for the life cycle considerations of the enterprise. These include the current enterprise definitions, the desired enterprise definition, and the migration path.

3. Procedures and tools that allow for the development of a particular enterprise's structure and models, as well as development of specific problem solutions.
4. Methods and tools to verify/test decisions prior to their implementation.
5. An open, heterogeneous, integrated processing system which supports the enterprise engineering and operating environments of the enterprise.

In the future environment of integrated data sharing, this framework will promote the improved competitiveness of US industries only if its concept, methods, procedures, and tools are broadly accepted and used by industry. The competitive standing of each individual enterprise will be a function of how the framework is applied toward solving the specific issues of the global competitive marketplace.

EXISTING INITIATIVE POSITIONING

An initial review of the framework elements contained within the AMICE CIM-OSA and SEMATECH CIM Architecture Concepts Guide was conducted concurrent with the requirements development (see previous section). This review concluded both initiatives addressed the problem through structured description of the enterprise (model) and an open integrated system environment. Either existing conceptually defined framework could be used as a starting point for a national consensus framework. An initial selection of CIM-OSA as a baseline resulted. The basis for the selection of CIM-OSA was its approach to standards (ISO) status and structure as defined in the "CIM-OSA" framework. This structure was reviewed at the first EIFWG. The EIFWG supported the CIM-OSA structure (framework) as a starting point and requested that other programs be positioned against it. The primary questions to be answered in the positioning were domains of the enterprise being considered, technology considered, and the level of program definition (life cycle position).

IBM and the Northrop/DACOM teams initially performed independent program positioning. These assessments were made through documentation review and discussions with initiative participants. At the second EIFWG meeting an initial review of the positioning was presented. At the meeting the decision was made to jointly complete the initiative positioning.

An EIF National Initiative Positioning Report was published by DACOM: this contains the results of the joint study positioning. In the report the initiatives were positioned from the following viewpoints:

- The types of users within and external to the enterprise that the programs addressed.
- The product life cycle phases addressed.
- The enterprise life cycle phases addressed.
- The variety of technologies addressed.
- The enterprise processes and information areas addressed.
- The current level of definition relative to implementation.

A total of thirteen initiatives were reviewed. CIM-OSA was identified as the initiative which incorporated the most complete viewpoint of the enterprise as a system. This result was subsequently confirmed by the Scenario Investigations. The major findings included:

- When the composite viewpoint of the thirteen initiatives was evaluated, the majority of the enterprise was not being addressed.
- There was significant overlap in the areas being addressed by the initiatives.
- A number of initiatives were at the conceptual level of definition. If action is taken quickly, these programs provide the best opportunity for cooperative development.

A summary of the findings is included in the Conclusions Section and cross references to the specific recommendations are given.

A finding from our discussions with the program participants was that the value associated with consensus actions was recognized. However, the detractors for the consensus between initiatives are time and resource constraints, current deliverable commitments (contractual obligations), and the lack of a recognized common framework.

SCENARIO INVESTIGATIONS

The scenario investigations were initiated after the first EIFWG. The objectives of the scenario investigation was to describe the Enterprise Integration Framework concepts, their application in an enterprise engineering environment, and any derived benefits. The scenario report was based upon the CIM-OSA framework. The report includes:

- A tutorial on CIM-OSA which introduces the concepts included in the framework and the integrating infrastructure.
- A roadmap for using the framework to evolve the enterprise to an open systems environment consistent with the enterprise needs and objectives.
- A life cycle methodology for developing the necessary enterprise descriptions (models), the associated framework elements, the purpose of each framework element, and the resulting benefits.

CIM-OSA incorporates two architectures, an enterprise descriptive architecture (framework composed of models) and an integrated data processing environment. The descriptive architecture describes the elements of the enterprise in a processable form (executable model). The integrated data processing architecture provides the environment which supports enterprise engineering (modeling, simulation, and decision making), application development, and the enterprise operational environment. Various aspects of the framework, their definitions, and the benefit of applying the framework are shown in Table 1 on page 10.

Table 1. Key Framework Aspects		
Attribute	**Description**	**Benefit**
Business Descriptive Language	The definition of the aspects and their relationships of the enterprise which need to be described to establish a "system view" for business management and enterprise engineering. Initial definition of these aspects provided in the IDEF methodology has been extended by CIM-OSA Generic Models.	The definition of the aspects will allow the opportunity for business understanding, business process simplification, and the sharing (integration) of business activities. An initial focus on data integration is expanding into process and activity integration. A key benefit is things that are described will be separately controllable and rapidly changed.
Partial Models	The completed descriptions for aspects enterprises have in common. The partial models can be applicable across or within an industry segment, and provide the basis for agreements upon which integration can occur. Examples would include PDES and EDI specifications.	Electronic exchange of data has demonstrated improved responsiveness and quality. Process simplification and increased inter-dependency between enterprise processes (equivalent to concurrent engineering) will proved even greater returns from a quality, cost effectiveness, and responsiveness standpoint. Partial models represent a shared investment in definition and resources
Computer *Processable*	A language and associated integrated *environment which captures the* business descriptions and provides processing capabilities to support the enterprise operation.	A seamless transition, which includes *simulation, from* the models to the operating environment provides the basis for rapid and cost effective change.
EIF Repository	The key element in the integrated environment which facilitates operation and integration within the enterprise. The three schema concepts of IISS are extended to enable dynamic use of the framework and operation of the enterprise.	A key technology focus to facilitate open, heterogeneous, integrated environment. The dynamic features will preserve concurrent operation of legacy systems and evolving new technologies

The scenario investigation indicates that the support methods and tools for the framework are incomplete. The scenario investigations included a mapping of the framework required elements to the IDEF methodology developed by the Air Force ICAM project. Significant improvements to the IDEF methodologies were suggested as a result of this mapping.

A significant concept is the use of Reference Models. Reference models can be defined at a requirements, design, or implementation level. These models are intended to facilitate business process interaction, consistent information definition, and identification of common activities; this would support both inter enterprise integration and application development efficiencies. The concepts and specifications for supporting tools need to be validated through application of the framework.

The findings from the scenario investigation included:

- Reference models consistent with inter and intra enterprise integration at the process levels are not defined.
- Generally, available models are not executable.

- The methodology and support environment for CIM-OSA needs to be validated and additional tools developed.

A summary of the findings is included in the Conclusions Section, and cross references to the specific recommendations are given.

TECHNOLOGY INVESTIGATIONS

The technology investigations focused on enterprise modeling and an open system repository.

Enterprise Modeling

The enterprise modeling investigations were performed by the Rennselear Design Research Center and included three activities:

- A sample portion of CIM-OSA was evaluated by translation to the EXPRESS language.
- An assessment of modeling languages for enterprise information.
- An assessment of the applicability of modeling languages to the EIF life cycle methodology modeling requirements.

The conversion of a small portion of the CIM-OSA model into EXPRESS was found to be an enlightening and a frustrating process. It was enlightening in the sense that it forced a close reading of the CIM-OSA documentation, and thus, led to a much greater understanding. It was a frustration because many details were missing from the CIM-OSA documentation. The formation of the EXPRESS model identified gaps in the CIM-OSA definition. This result indicates that a step in the further development of CIM-OSA should be a rigorous application of EXPRESS in the CIM-OSA construct definition.

Existing information modeling technologies were compared to identify their respective capabilities. The modeling languages considered the formally specified graphic data modeling languages IDEF1X and NIAM; the informally defined graphics language suggested by Shlaer-Mellor; and the formally specified textual programmatic information modeling language EXPRESS. The EXPRESS language is a superset of the other languages; it supports the modeling of complex constraints; and since it is a programmatic language, it is computer processible. From the PDES/STEP experience, there is something to be gained by modeling in two or more languages, as each forces a different viewpoint onto the modeling process. If the modeling language does not support constraints, then these tend not to be considered, in spite of the fact that constraints are a vital ingredient of a complete and robust information model.

STEP has shown that multiple modeling methodologies and representations are an aid to human understanding and improve both the quality and efficiency of model development. However, there must also be a clear understanding that one and only one of the model representations is the 'master' or 'legal' form. STEP has also demonstrated that the necessity for computer processible representations. It selected EXPRESS as its master language, as it was inherently processible.

CIM-OSA, and hence the EIF, is an attempt to define an architecture for describing the activities of an enterprise. The architecture is based upon successive refinement from the most general concepts to the very particular instantiation within a specific business location. CIM-OSA has only really provided a preliminary sketch of what is to be done. Perhaps the largest modeling effort to date is occurring within the PDES/STEP project. Unlike STEP, which is concentrating on modeling the information necessary to define a product, EIF modeling also includes activity or process modeling as well as the information modeling. Thus these two types of models must be integrated. EXPRESS can be used for activity modeling, as demonstrated in the in the sample portion discussed above; however, a processible language designed for this purpose is likely to be more efficient. An example of an existing activity processible language would be Estelle. Estelle was defined and is used within the OSI standards activity to define the transaction nodes. To

obtain the modeling integration required by EIF will necessitate some form of modeling language and tool integration.

At a somewhat higher level, developing an EIF model will be similar to developing an extremely large software system, with added disadvantage that there is virtually no experience base, apart from STEP. At a conservative estimate, an EIF will be at least an order of magnitude larger that STEP. It will be absolutely essential to have a "EIF system architect" to act in the same manner as a software system architect.

The findings from the modeling investigations included:

- An enterprise model is a combination of process and information models, and the use of an integrated form of the EXPRESS and Estelle languages may provide the "master" EIF model languages.
- Use other (e.g. graphical) forms of model presentation for explanatory and developmental purposes.
- There are few tools available to modelers.
- An EIF system architect is required to manage the complexity.

A summary of the findings is included in the Conclusions Section and cross references to the specific recommendations are given.

Repository Investigation

Central to the integration of any enterprise is the business-wide sharing of information about the enterprise objectives, data, processes, policies, rules, procedures, resources, and organization. In order to accomplish this, a central logical access to all enterprise data must be provided.

Although the concept of a repository is accepted by the initiatives evaluated, there is no consistent definition of its behavior, functions and contents. The EIF Repository Investigation included a review of the following considerations:

1. Technology issues.
2. High level requirements.
3. Architecture.
4. Applicability to CIM-OSA Integrating Infrastructure.
5. Architecture vs. Applicable Technology.

An EIF repository architecture based upon object-oriented principles and utilizing thirteen (13) object managers to control different characteristics was defined. This repository provides for the inclusion of legacy information systems and is extendable to incorporate new technology as it is developed. Legacy information is defined as objects within the repository through the use of wrappers. These wrappers allow the legacy system to interact with the other objects within the repository. The dynamic aspect of the repository provides for the execution of enterprise activities based on triggers within the repository. The object manager objects are themselves described in terms of the thirteen managers allowing the definition objects as well as other objects to be free to change and evolve. By providing for the evolution of the repository as new technology becomes available, the EIF repository truly is able to grow and operate as an open systems environment.

As described in the Repository Report, the repository accepts and implements the CIM-OSA concepts, and includes the CIM-OSA Communication, Information, Front End, and Business Process Services. A summary of the findings is included in the Conclusions Section, and cross references to the specific recommendations are given.

CONCLUSIONS

The Enterprise Integration Framework Study objective was to define for national consensus a strawman framework that would promote US industrial competitiveness through enterprise integration. This strawman national framework for inter and intra enterprise integration was to be based on:

- Open Systems.
- National and international standards.

The five questions identified in the Problem Statement were resolved as follows during the study contract:

1. THE DEFINITION OF THE FRAMEWORK - The framework must accomodate all aspects, from definition of goals and objectives (by some method) through the information systems architecture which enables systems development to further these objectives.
2. THE BOUNDARY DEFINITION OF THE FRAMEWORK - It was determined that the CIM-OSA framework provided a complete definition of the boundaries.
3. THE NEXT LEVEL OF DETAIL THAT IS NEEDED TO FURTHER DEFINE THE BOUNDARIES - The CIM-OSA framework extensions currently being developed by AMICE are defining the lower level boundary definitions. A co-operative development activity with AMICE was included as a recommendation to accelerate and define at an implementation level the boundary descriptions.
4. THE RULES .... NEEDED TO GUIDE THE FRAMEWORK - An outline of the rules, procedures, guidelines, etc. were outlined in the EIF Scenario Investigations. An approach to the open system requirements for information systems integration was outlined in the Repository Investigation. Recommendations for the consensus based refinement of these and other EIF required rules, procedures, etc. are provided.
5. SOLUTIONS .... OF THE COMPETITIVENESS ISSUES - The development of reference models presents an opportunity for U.S. industry competitive improvement. The development of a inter enterprise reference model for the DoD acquisition process was recommended as a test case for substantiating the benefits that could be realized.

The study results concluded that a strawman was provided by the CIM-OSA concepts; however, the specifications and supporting environment for CIM-OSA are still in development. US initiatives are developing equivalent concepts for parts of the framework; however, a migration plan reflecting convergence of the concepts needs to be defined. The methodology for the application of the CIM-OSA concepts was postulated; but, the EIF methodology needs to be refined through a consensus process, and a supporting integrated tool set must be defined. One of the tools concepts, an EIF Repository, was described. The objective of the EIF Repository is to enhance open systems definition by providing a dynamic self-adapting meta-structure framework. The CIM-OSA concepts are currently in the international standards process, and no equivalent US standard is in development.

The EIF Study confirmed that CIM-OSA could be used as the foundation for an Enterprise Integration Framework. The framework will require the completion of the CIM-OSA specifications, refinement of an enterprise integration methodology, development of the engineering support environment (tools), and establishment of compliant reference models and products. Although the compliant products and models are not developed, industry and government can begin using the concepts with existing capabilities and migrate as the compliant products become available. Initiation of the development of reference models, based on CIM-OSA compliant products and models, will provide a basis for validation of the concepts, refinement of the specifications, and quantification of the benefits.

The following sections summarize the findings and recommendations.

SUMMARY OF FINDINGS

The following tables summarize the findings from the various study activities performed on the EIF Study Contract. These findings are cross-referenced to the recommendations for follow-on actions. (e.g. identification of the Recommendation Topic - Action Number (III-3))

RENSSELAER DESIGN RESEARCH CENTER REPORTS

FINDING FROM MODELING INVESTIGATIONS	RECOMMENDATION NUMBER
CIM-OSA Modeling 10 Times More Complex Than PDES	III-3
Integrated Tool Set Not Available	III-3
Require One Language As A MASTER For Control	III-2
Enterprise Model Is A Combination Of Models	I-1
Master Language May Vary With Model Function (e.g. ESTELLE for PROCESS, EXPRESS for INFORMATION).	III-2
Constraint Representation Is A Critical Requirement	IV-2
CIM-OSA Provides A Preliminary Sketch Of What Is To Be Done	IV-2
Using More Than One Model Leads Results In A Better Understanding	I-3
Require EIF SYSTEM ARCHITECT	I-1

NATIONAL INITIATIVE POSITIONING

PRELIMINARY FINDINGS IN EIFWG PRESENTATION	RECOMMENDATION NUMBER
Major Focus Information Analyst Viewpoint	I-4
Customers, Executives, Users Needs Least Focus	II
Less Than Half Of Enterprise Examined	I-6
Design and Manufacturing Process/Information Most Overlap	I-5
Resource and Organization Have Limited Coverage	II
Necessary Technical Breadth Recognized By Programs	N/A
Only CIM-OSA Encompasses All Of The Enterprise	I
Broader Scope Programs In Conceptual Development	I-5
Architectures Lag Development In Some Programs	I-1

FINDINGS IN JOINT POSITIONING REPORT	RECOMMENDATION NUMBER
Candidates For Co-operation	I-5
Candidates For Future Development	I-6
Methodology, OSA, Communications Strong Candidates For Co-ordination Across Programs	I-5
Management and Support Functions Receive Little Attention	I-6
Information Management and Product Information Areas Are A Common Focus For Many Programs.	I-5
Majority Of Enterprise Not Being Addressed	I-6
Broader Scope Programs Are In Conceptual Phases, Providing The Potential For Increased Commonality If Action Is Taken Now.	I-5
Architectures Lag Development In Some Programs	I-1

EIF SCENARIO INVESTIGATION

FINDINGS IN REPORT	RECOMMENDATION NUMBER
Incomplete Enterprise Life Cycle Methodology	I-2
Incomplete Process Behind Methodology	I-3
Incomplete Support Environment	III-3
Inter- and Intra Enterprise Integration (Context At Process Level) Not Defined	II
Models Not Executable	III-3

EIF REPOSITORY INVESTIGATION

FINDINGS IN REPORT	RECOMMENDATION NUMBER
Need For Repository As Central Information Access Point	III-1
There Is No Agreed Upon Definition Of Repository	III-1
No One Addressing All Repository Needs	III-4

RECOMMENDATIONS

The recommendations address refinement of the architectures and methodology of the Enterprise Integration Framework. Specific recommendations are made for technology developments to address framework consistent tools and an information repository. The recommendations include follow on actions for establishing a US interface into the pre-norm international standards activity of AMICE and through this US interface also establish a migration plan for US initiatives to provide the basis for building national consensus consistent with international standards directions.

Recommendations are included in the following topical areas:

1. CONCEPT
2. TEST CASE
3. DEVELOPMENT
4. VALIDATION
5. DEMONSTRATION
6. CIM-OSA ACTIONS

For each topic the following are provided:

1. RECOMMENDATION - High level statement of suggested direction.
2. WHAT ACTION - Suggested specified actions.
3. APPROACH - A short description.

I - EIF CONCEPT

RECOMMENDATION

Implement a common architecture starting with the CIM-OSA definition. Incorporate existing and future DoD Initiatives in refining, extending, and validating the CIM-OSA definition.

ACTIONS

This recommendation can be facilitated by the following actions:

1. Designate An Agent To Be The SYSTEM ARCHITECT
2. Achieve Consensus On Enterprise Integration Roadmap
3. Achieve Consensus On Methodology Process
4. Adopt A Business Descriptive Language
5. Develop Role/Relationship For Existing Programs
6. Provide Guidance To New Programs

APPROACH

These actions should include the following considerations:

- Establish a working relationship for the continued development and refinement of CIM-OSA with the AMICE.
- Establish a consensus based US Architecture Program responsible for execution of US CIM-OSA refinement activities.
- Initial actions required include refinement of the EIF roadmap describing enterprise application of CIM-OSA and validation of the associated methodology process.
- Based on CIM-OSA definition and CALS STANDARDS ROADMAP, develop a joint AMICE DoD standardization plan.
- Existing program and consortium activities should be incorporated into consolidated approach, e.g. assign specific standards to programs and/or consortiums.
- Existing programs can provide technology demonstration for required concepts, specific outputs as draft specifications, and assessment of the applicability of technology.
- Future programs can be defined to accelerate key technology and additional enterprise processes.

II - CALS TEST CASE

RECOMMENDATION

As a Test Case, define a common DoD Procurement Process description utilizing/extending the EIF Roadmap and Methodology in a consensus process to provide a model for inter-enterprise integration between Government and Defense Industry.

ACTIONS

This recommendation can be facilitated by the following actions:

1. Assign authority to Joint Service Task Force.
2. Incorporate Industry Participants For Prime/Major Subcontractor/Supplier Roles.
3. Develop Particular Models, Generic Building Blocks, and Partial Models Applicable To DoD.
4. Assign An Integration Contractor To Manage Task Force/Industry Participation in accordance with the CIM-OSA and the U.S. System Architect.
5. Document Strategic and Migration Plans Based On The Above Actions.

APPROACH

These actions should include the following considerations:

Initiate a CIM-OSA Case Study to improve the responsiveness and concurrency allowable in the government acquisition process. Evaluate the current government acquisition processes and industry processes (AS-IS) which interface with the government to define alternate process approaches (TO-BE). Result should provide advanced definition (Strategic Plan) for government and industry process integration opportunities to achieve the CALS objectives. The next step would be to define an Implementation (Migration) Plan.

III - DEVELOPMENT

RECOMMENDATION

Plan incremental introduction of EIF, through development of consistent technology capabilities in modeling, processing services and applications.

ACTIONS

This recommendation can be facilitated by the following actions:

1. Develop A Detailed Repository Architecture Specification.
2. Adopt A Computer Processible Language.
3. Build Consensus On Tool Set Requirements For The Methodology.
4. Sponsor An Advanced Development Program To Demonstrate An EIF Repository and Tools Per Specification.

APPROACH

These actions should include the following considerations:

- Define a migration plan to converge modeling, data processing services, and applications capable of using the processing services.
- Develop technology extensions to facilitate the ease of implementation in three areas starting immediately:
  1. Extend existing tools, like IDEF, to more completely model the processes, provide computer processable results, and act as a flexible integrated tool kit. Apply the resulting tools across enterprise process analyses conducted for CIM, CE, CALS, TQM, etc.. Incorporate model outputs in computer processible form as basis for legacy integration and migration.
  2. Define a computer processible language for the above consistent with the descriptions required to support the modeling and enable data processing services functions. Evaluate EXPRESS, ESTELLE, ISyCL, and others to formulate a specific recommendation to be incorporated into CIM-OSA.
  3. Develop a repository architecture based on the initial EIF repository recommendation report. Initiate a dynamic repository technology development based upon demonstrated CDM technologies. Demonstrate self-adaptability features of repository by responding to new alternative underlying technologies from multiple vendors. Include the identification and integration of existing standards (CIM-OSA, IRDS, PDES, etc.) and if necessary, development of new standards.

IV - VALIDATION

RECOMMENDATION

Validate The Feasibility Of Integrating Existing Information Models Into A CIM-OSA Reference Model And Define Support Tool Requirements.

ACTIONS

This recommendation can be facilitated by the following actions:

1. Extend CIM-OSA EXPRESS Definition
2. Integrate PDES, EIS, and DICE PPO Within CIM-OSA.

APPROACH

These actions should include the following considerations:

- Using the current EXPRESS definitions from PDES, EIS, and the DICE PPO, integrate these models with the CIM-OSA constructs.
- Validate the CIM-OSA constructs and define refinements/extensions.
- Define the PDES architectural relationships with CIM-OSA, identify tool requirements, assess the role and effectiveness of a computer processible language using EXPRESS as the tentative target, and determine the feasibility and limitations associated with model integration.

V - DEMONSTRATION

RECOMMENDATION

Demonstrate Resulting Capabilities In Selected DoD Industry Sites.

ACTIONS

This recommendation can be facilitated by the following actions:

1. Define Partial Model For DoD/Industry Use
2. Develop Site Specific Particular Models Based On Partial Model
3. Implement Integrating Infrastructure Components
4. Perform Pilot Operations

APPROACH

These actions should include the following considerations:

- Establish CIM-OSA demonstration environments consistent with the incremental release of CIM-OSA capabilities.
- Develop a Migration plan to show the evolution of the CIM-OSA architecture, data processing services specifications, model development, and compliant products.
- Conduct modeling activity utilizing EIF Methodology and CIM-OSA Constructs to identify required improvements.
- Tailor tools to the defined CIM-OSA capabilities.
- Incorporate infrastructure and application products from multiple vendors.
- Substantiate the benefits derived during the development and resulting from operating in a CIM-OSA environment.

CIM-OSA ACTIONS

RECOMMENDATION

Designate a U.S. interface who will coordinate the CIM-OSA actions directed toward AMICE.

ACTIONS

Define cooperative/co-development plans with a U.S. Government agency to:

1. Improve availability of
   - AMICE Restricted Data
   - AMICE Published Data (Conference Presentation, etc.)
2. Define Standards Plan and Strategy
3. Provide Broad Base of Education and Documentation for:
   - Executive
   - Enterprise Engineer
   - Information Analyst

APPROACH

We recommend that AMICE assume the lead in addressing the three items that are shown. If we are to have a successful start to building a joint enterprise integration framework, items one and four must be given priority.

The CIM-OSA concepts, as are the problems of enterprise integration, are complex. If cooperation and consensus are to be successful, then a broad audience must have access to and understand the current state and direction of the CIM-OSA definitions and AMICE's plan.

All of the actions can begin to be formed when AMICE, in the role of the catalyst, appoints a U.S. interface and has a designated U.S. representative with whom to work.

ACRONYMS

AMICE European Computer Integrated Manufacturing Architecture consortium. One of the ESPRIT projects.

CIM-OSA Computer Integrated Manufacturing - Open System Architecture. The result from the AMICE consortium which is being submitted to the International Standards Organization.

DARPA The Defense Advanced Research Projects Agency.

ESPRIT European Strategic Programme for Research and Development in Information Technology supported by the European Communities.

Estelle Language designed for specification of distributed concurrent processing systems, utilized within the communications protocols and services of the ISO Open Systems Interconnection architecture.

EXPRESS Language developed by the PDES/STEP international standards community for the purpose of information modeling.

SEMATECH SEmiconductor MAnufacturing TECHnology is a consortium of U.S. semiconductor manufactures that sponsors and conducts research in semiconductor manufacturing technology.

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Appendix A. CIM-OSA EXAMPLE

The following paper summarizes the CIM-OSA Framework and provides an example application of the constructs.

MODELLING AND ANALYSIS OF ENTERPRISE INFORMATION SYSTEMS WITH CIM-OSA (c) written by F. Vernadat and presented at CIM Europe 90 , Lisbon, Portugal, 15-17 May 1990.

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